AEROLOGICAL OBSERVATIONS

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There appear in this issue of the MONTHLY WEATHER REVIEW several important changes in and additions to the aerological data as presented heretofore. Data obtained by airplane flights and those obtained by radiosonde observations are presented as formerly in tables 1 and 1a, respectively.

The table presenting free-air resultant wind data (table 2) is expanded, data being published for 39 stations instead of 26 stations as previously. Moreover, these resultant wind data are based on observations made at 5 p. m. (E. S. T.) instead of 5 a. m. Data are shown in table 2 for any level if 10 observations or more were recorded at that level during the month; data as published in table 2 previously were based on 5 or more observations. Table 2 is further extended to upper levels showing data for the same levels as before and in addition data are shown for each higher even-thousand meter level at which 10 or more observations were recorded. As an aid in the interpretation of these data of table 2 the number of observations at each level for every station is shown as a small figure following the velocity.

Maximum wind velocities observed in the free air during pilot balloon flights are shown in table 3 as has previously been done.

Data setting forth the various heights of the tropopause during the month will appear as table 4. These data have not previously been shown.

In addition to the new and changed tabular material there appear in this summary five new charts. Charts VIII to XI show the resultant winds, the isobars and the isotherms at four upper levels, while chart XII presents an isentropic surface.

Table 4 and chart XII, and the discussion relating to them, have been prepared by the Air Mass Section of the Bureau.

In general, much more data appear in chart and tabular form than have previously been shown. These data are described and discussed below in detail.

The mean free-air pressures for the month as shown in tables 1 and 1a and charts VIII to XI, inclusive, indicate that the lowest pressures of the United States occur over the Northern Great Lakes; Sault Ste. Marie, Mich., having the lowest pressure observed within the United States for all levels above the surface up to 8,000 meters. At 10,000 meters and above, the low pressure area expands westward with equally low values recorded over Fargo and Sault Ste. Marie. Data are not available for stations in the extreme north and northeast except for Newfoundland. Based largely on these data and as shown by isobars drawn on charts VIII, IX, and X, there appears to be still lower pressures north of Newfoundland at levels from the surface up to at least 4,000 m. (m. s. l.). At all levels from the surface up to and including 5,000 m. pressure was highest at Pensacola, Fla.

The pressure gradient increases with altitude for levels from 500 to 5,000 meters. The difference in pressure between Pensacola and Sault Ste. Marie being 16, 24, and 29 mb. at the 1,000, 3,000, and 5,000 m. levels, respectively.

Mean free-air temperatures (°C.) (tables 1, 1a, and charts VIII to XI) above the surface are well distributed, and below 11,000 m. are in general colder with increasing latitude. At these levels the coldest upper-air layers were noted over northern Minnesota and the upper Great Lakes and to the northeastward while the warmest layers were over the Gulf Coast and the southern part of the United States. Mean free-air temperatures were below 0° C. over all the United States and Canada at and above 4,000 meters above sea level. As shown by table 1a, data for levels above 5,000 m. are available this month for 6 stations east of 100° W. longitude and north of 35° N. latitude and for Oakland, Calif., on the west coast. For levels between 11,000 m. and 18,000 m. the coldest layers of air are found over Nashville and the warmest over Sault Ste. Marie. The lowest mean free-air temperature shown is −72.2° C. (−98.0° F.) at 19,000 m. (62,336 ft. or 11.8 miles) above sea level over Nashville.

Mean relative humidies are highest in most air layers above the surface over northern Minnesota and the Northern Great Lakes. This area of relatively high humidity is roughly the same as corresponding areas of low pressures and low temperatures, especially at lower and intermediate levels. There is also an area of higher humidity over Utah and Nevada reaching from about the 1,000 m. level to the 4,000 m. level. The lowest relative humidities occur in general in connection with the regions of higher temperature near the Gulf and over Texas and southern New Mexico in the lower and intermediate levels. The lowest mean relative humidity for the month was 27 percent which was recorded at 5,000 m. above sea level over Pensacola. The relative humidity values shown in connection with temperatures below −40° C. are discarded as inaccurate, this accounts for the absence of humidity data for the higher levels in table 1a.

Resultant winds, indicating the mass transport of air in the free atmosphere, and based on pilot-balloon observations made near 5 p. m. (E. S. T.), are shown in table 2.

These resultant winds, when compared with the 5 a. m. (E. S. T.) normal resultants for this month show a distinct tendency toward a counterclockwise turning, from the normal over the eastern part of the country and the opposite tendency, a clockwise turning, over the western part of the country up to 1,500 meters. At 2,000 meters and above corresponding departures were not clearly separated. Departures were counterclockwise at all levels for five stations: Chicago, Omaha, Oklahoma City, Nashville and Atlanta. At only one station, Seattle, Wash., were departures clockwise at all levels.

The 5 p. m. resultant winds, as shown by table 2, are in general from westerly directions at all levels over the United States. Exceptions are noted at Las Vegas, Brownsville, Houston and Miami for the surface level, at Brownsville and Miami for the 500 m. level, and at Miami, Las Vegas, and San Diego for the 1,000 m. level. Resultant winds are westerly at all higher levels without exception.

With but very few exceptions the resultant velocity increased with elevation at all stations during the month. It is also noted that the resultant velocity was considerably above the 5 a. m. normal over most of the area. The resultant velocity was above normal at all levels, including surface, at eight widely scattered stations: Albuquerque, Cincinnati, Nashville, Oakland, Oklahoma City, St. Louis, Seattle, and Spokane. Resultant velocities were well below normal for all levels at Fargo, for all except lowest levels at Sault Ste. Marie, and for the intermediate levels at Omaha and Cheyenne. The maximum resultant velocity for the month, 27.3 meters per second (60.8 miles per hour) was recorded at the 6,000 m. level at Greensboro, N. C.

Table 3 shows the maximum free-air velocities which were recorded during the month in each of the three atmospheric layers, surface to 2,500 m., 2,500 m. to 5,000 m. and above 5,000 m. The maximum free-air velocity which was recorded during the month for the lowest of these three layers was 47.8 meters per second (106.9 miles per hour) reported on January 25 at 900 meters above sea level over Albany, N. Y. The corresponding maximum for the 2,500 to 5,000 m. layer was 63.4 meters per second (141.8 miles per hour) reported January 26 at 4,320 meters above sea level over Greensboro, N. C.; while the maximum for over 5,000 meters elevation was 95.5 meters per second (213.6 miles per hour) at 8,440 meters (5.2 miles) above sea level over Albuquerque on January 14.

This Albuquerque maximum establishes a new record for free-air velocities surpassing the previous record of 90 meters per second reported November 14, 1938, at Winslow, Ariz. The Albuquerque balloon flight of January 14 was observed with a single theodolite and was made with a large 100-gram balloon. Careful examination of the data of the particular flight as well as the evidence of balloon flights at other nearby stations that day indicate that the 95.5 meters per second velocity, while a very large value, can probably be accepted as correct. One reason for believing this a true velocity, and not a result of a slowly leaking balloon, is that above the 8,440 m. level the velocity decreased regularly at higher levels until at the maximum, 10,124 meters (6.3 miles), the velocity was only 25 m. per second (55.9 miles per hour).

In connection with the maximum velocities for the month, it is interesting to note that the mean of the maximum velocities for the lowest layer over the nine sections of the country is 41.4 meters per second (92.6 mi./hr.), the corresponding mean for the 2,500 to 5,000 m. layer is 52.3 meters per second (117 mi./hr.) and the mean for above 5,000 meters is 65.5 meters per second (146.5 miles per hour). Above 5,000 m. one maximum wind was reported from a direction south of west, one from the west, the seven others were all from direction to the north of west.

Chart VIII shows the 5 a. m. (E. S. T.) resultant winds for the 1,500 m. level. Isotherms are also drawn for this level. To permit the use of the 5,000 ft. pressures available for a large number of western stations, isobars are drawn on this chart for the 1,524 meter (5,000 ft.) level.

Chart IX shows data for the 3,000 m. level corresponding to that given on chart VIII.

Charts X and XI show corresponding data for the 4,000 and 5,000 m. levels, respectively, except that the resultant wind data is based on observations made at 5 p. m. (E. S. T.).

The decision to use the 5 p. m. observations for resultant wind data for the two upper levels, as shown on charts X and XI, was prompted by the fact that in the Bureau, records for most stations show that a considerably greater number of observations reach these levels at that time of day than at 5 a. m. Furthermore, it is believed that the diurnal variation of winds, at these levels, is on the average, sufficiently small to justify the use of the greater number of observations although made some 12 hours later than the temperature and pressure observations with which they are charted.

Data shown on charts VIII to XI for stations within the United States and Canada are based on observations at 5 a. m. and 5 p. m. (E. S. T.) as shown above. The resultant winds shown on these charts for St. Julian, Cuba, are based on 7:30 a. m. (E. S. T.) and those for Antilla, Cuba, on 6:30 a. m. (E. S. T.). Corresponding data for Mazatlan, Mexico, are based on observations at 11 a. m. (E. S. T.); those for Hermosillo, Mexico, on 9 a. m. (E. S. T.); the 1,500 and 3,000 m. resultants for Tampico, Mexico, are based on 8 a. m. (E. S. T.) observations and those for the two higher levels for the same city on 2 p. m. (E. S. T.) observations. The resultant winds shown on these charts for Bermuda are based on pilot-balloon observations taken between the hours of 6:30 and 9:30 a. m. (E. S. T.).

TROPOPAUSE DATA

Table 4 is a summary of tropopause heights and temperatures for January 1939 prepared by the Air Mass Section of the Weather Bureau, and based on radiosonde observations. In summarizing these data, instead of designating a single tropopause for each sounding determined by the existence of a discontinuous change of temperature lapse rate equal to or greater than some arbitrarily prescribed value, the idea of a "multiple tropopause" as suggested by J. Bjerknes and Palmén [1] has been followed. These authors found that if an arbitrary rule is followed in which the tropopause is defined as the level where the temperature gradient definitely sinks below a certain limit, for instance 2° C. per 1,000 dynamic meters, the tropopause would change in certain cases from hour to hour at a given station due to a point as much as 1,000 meters higher or lower changing its temperature by 1° or 2°. When a network of stations is considered, the difficulty becomes even greater. A tropopause found at one station would, according to the usual method of identification of significant points in a station network by potential temperature, correspond at another station to some temperature inversion rather low in the troposphere or perhaps some minor discontinuity high in the stratosphere. Bjerknes and Palmén showed that in some individual soundings a single, well-defined tropopause is evident, but in many cases several significant points can be designated as tropopauses. At a given time each of several significant tropopause points at one station usually is associated with corresponding significant points at other stations, but the particular point most likely to be designated as the tropopause from the usual arbitrary rules at one station may not correspond with the significant point similarly selected for the tropopause at any other place. Consequently, it is advisable to consider each significant point, at least within certain limits, as representing a possible tropopause. Bjerknes and Palmén suggested that these "multiple tropopauses" be classified according to potential temperature, as that is the principle element used in identifying significant points.

In table 4 the multiple tropopauses are classified according to 10-degree ranges of potential temperature from 290°A to 399° A. All significant points in this interval of potential temperature showing a decrease of lapse rate were tabulated from the daily ascents at each station. Points at which the temperatures were higher than −25° C. were not considered. The mean altitude and mean temperature of points occurring in each 10° interval of potential temperature have been entered in the second and third columns for each station in the table and the number of cases in the first column. The weighted mean altitude and temperature for all cases over the entire 110° interval appears at the bottom, and finally the weighted mean potential temperature for all cases at each station is given. In spite of the rather arbitrary limits (temperatures lower than —25° C. and potential temperatures

[1] Bjerknes, J., and Palmén, E.: Investigations of selected European cyclones by means of serial ascents, Norske Videnskaps-Akademi, Geofysiske Publikasjoner, Vol. 12, No. 2, 1937.

from 290° to 399°) the summarized result gives reasonable values.

Apparently this is the first time that mean tropopause data have been summarized in this form. It is possible that with more experience in this procedure it will be necessary to make minor changes.

MEAN ISENTROPIC CHART

Chart XII represents a mean isentropic chart for the month of January 1939, using a potential temperature of 295° A.

The chart has been constructed in accordance with methods used in the Air Mass Section of the Weather Bureau, and described in a circular letter of September 29, 1938. The data used are the mean free-air data from APOB, RAOB, and pilot-balloon stations published elsewhere in this issue of the REVIEW. It was necessary to use a few resultant winds from the 5 p. m. observations, and these are designated by the letters (P. M.) printed near them. At stations where the height of the isentropic surface is only roughly estimated, because of insufficient data, the winds are plotted at the altitude indicated.

It is realized that air flow is not even approximately isentropic over a period of a whole month, but presumably a mean isentropic chart will give a better indication of the sources and mean trajectories of moist and dry air than would a constant level chart.

A study of mean isentropic charts indicates that precipitation areas are correlated with the position of moist and dry tongues. In the winter months the greatest areas of positive departure in precipitation are found to lie to the north of the moist tongues, where the upflow is most pronounced, whereas in the summer time they lie farther within the moist areas.

TABLE 1.—*Mean free-air barometric pressures (P) in mb, temperatures (T) in °C, and relative humidities (R H) in percent obtained by airplanes during January 1939*

Stations and elevations in meters above sea level	Altitude (meters) m. s. l.															
	Surface				500			1,000			1,500					
	Number of observations	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.			
Billings, Mont. (1,090 m.)	30	888	−0.1	59							844	1.4	52			
Cheyenne, Wyo. (1,873 m.)	31	807	−3.7	64												
Chicago, Ill. (187 m.)	29	993	−1.7	83	954	−1.9	81	896	−2.7	78	841	−3.6	70			
Coco Solo, C. Z.[1] (15 m.)	31	1,011	25.3	84	956	22.3	88	903	19.3	84	852	16.4	79			
El Paso, Tex. (1,193 m.)	31	883	2.7	55							851	6.6	45			
Lakehurst, N. J.[1] (39 m.)	22	1,015	−0.6	77	957	−0.5	70	900	−1.8	69	845	−2.6	61			
Norfolk, Va.[1] (10 m.)	19	1,020	4.2	87	960	5.4	80	904	3.2	70	849	2.3	61			
Pearl Harbor, T. H.[1] (6 m.)	31	1,016	20.9	80	960	20.1	73	906	17.0	80	854	15.4	70			
Pensacola, Fla.[1] (13 m.)	25	1,021	9.8	87	964	11.0	66	908	9.1	62	854	7.8	54			
St. Thomas, V. I.[1] (8 m.)	15	1,018	23.9	77	963	21.1	87	908	18.1	84	857	14.8	83			
Salt Lake City, Utah (1,288 m.)	31	873	−1.7	85							850	−0.5	75			
San Diego, Calif.[1] (10 m.)	29	1,017	8.3	84	960	10.4	77	904	9.0	68	851	6.8	61			
Seattle, Wash.[1] (10 m.)	20	1,017	6.1	83	958	4.0	79	901	0.7	79	846	−1.6	77			
Spokane, Wash. (597 m.)	30	947	0.7	87				901	−0.2	82	846	−1.4	71			

Stations and elevations in meters above sea level	2,000			2,500			3,000			4,000			5,000		
	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.
Billings, Mont. (1,090 m.)	793	−1.8	51	744	−5.2	53	698	−8.4	55	613	−14.6	59	536	−21.0	60
Cheyenne, Wyo. (1,873 m.)	794	−1.2	55	746	−3.1	52	700	−6.3	52	615	−12.9	52	539	−19.6	48
Chicago, Ill. (187 m.)	790	−5.7	69	741	−7.9	68	694	−10.3	64	609	−15.5	58	533	−21.3	56
Coco Solo, C. Z.[1] (15 m.)	802	14.2	70	750	13.2	48	712	11.4	35	631	5.6	35	558	0.4	22
El Paso, Tex. (1,193 m.)	800	4.4	41	752	1.8	40	706	−1.0	39	622	−6.8	38	546	−14.0	38
Lakehurst, N. J.[1] (39 m.)	792	−4.1	55	743	−6.8	52	697	−9.1	52	611	−15.3	53			
Norfolk, Va.[1] (10 m.)	798	0.3	58	750	−2.1	54	703	−4.5	48	619	−9.8	41	543	−16.5	38
Pearl Harbor, T. H.[1] (6 m.)	805	14.2	52	758	12.3	43	714	9.9	38	632	5.4	32	559	0.0	34
Pensacola, Fla.[1] (13 m.)	804	6.3	51	755	4.5	42	710	2.6	33	626	−3.3	28	552	−9.5	27
St. Thomas, V. I.[1] (8 m.)	808	12.2	74	761	10.8	57	716	8.6	45	634	4.6	30			
Salt Lake City, Utah (1,288 m.)	799	−2.2	71	750	−4.4	71	704	−7.3	70	618	−12.9	64	541	−18.9	56
San Diego, Calif.[1] (10 m.)	800	4.7	55	752	2.1	52	706	−0.6	49	623	−6.8	47	547	−13.3	46
Seattle, Wash.[1] (10 m.)	795	−4.5	75	745	−7.3	68	699	−10.4	67	612	−17.6	74			
Spokane, Wash. (597 m.)	794	−4.1	70	745	−7.1	74	698	−10.1	75	613	−15.5	70	536	−21.8	67

Observations taken about 4 a. m. 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

[1] Navy.

NOTE.—None of the means included in this table are based on less than 15 surface or 5-standard-level observations.

TABLE 1a.—*Mean free-air barometric pressures (P) in mb, temperatures (T) in °C. and relative humidities (R H) in percent obtained by radiosonde during January 1939*

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level															
	Fargo, N. Dak. (274 m.)				Nashville, Tenn. (180 m.)				Oakland, Calif. (2 m.)				Oklahoma City, Okla. (391 m.)			
	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.
Surface	31	981	−12.9	92	31	997	4.3	80	31	1,020	6.5	88	30	971	3.5	77
500	31	953	−10.6	91	31	958	4.7	76	31	960	7.9	77	30	957	4.8	73
1,000	31	893	−7.4	85	31	901	3.3	73	31	904	7.1	68	30	901	5.4	60
1,500	31	837	−6.9	80	31	847	1.8	65	31	850	5.4	62	30	847	3.7	55
2,000	31	785	−8.6	77	31	796	−0.2	60	31	799	3.4	55	30	796	1.4	49
2,500	30	736	−11.0	74	31	748	−1.9	54	31	751	0.6	51	30	748	−1.1	47
3,000	30	689	−13.8	72	30	702	−3.7	48	31	706	−2.1	50	30	702	−3.5	47
4,000	30	603	−19.6	70	30	618	−8.7	41	31	622	−8.3	50	30	618	−9.1	44
5,000	30	526	−25.5	66	30	542	−14.6	39	31	546	−14.8	50	30	542	−15.6	43
6,000	29	458	−33.0	64	30	474	−21.1	40	31	477	−21.2	49	30	474	−22.0	41
7,000	29	396	−40.5	63	29	414	−27.6	41	31	416	−28.1	48	30	413	−29.5	41
8,000	28	341	−47.4		28	359	−33.9	41	31	361	−35.2	48	30	359	−36.5	40
9,000	27	292	−52.2		28	310	−40.9	40	31	312	−42.5	48	27	309	−43.6	
10,000	27	250	−54.9		28	267	−48.0		29	269	−49.7		25	266	−50.1	
11,000	27	214	−55.0		27	229	−54.0		26	230	−55.2		23	228	−55.0	
12,000	27	183	−55.2		27	196	−58.8		25	196	−57.9		23	194	−58.2	
13,000	25	156	−56.2		26	166	−61.4		23	167	−57.9		22	166	−59.4	
14,000	21	134	−56.9		26	141	−63.4		22	142	−58.8		21	141	−60.8	
15,000	16	114	−58.7		23	120	−66.1		18	121	−60.3		17	120	−63.4	
16,000	12	97	−60.5		21	101	−69.0		16	103	−61.5		12	102	−65.9	
17,000	8	83	−61.1		17	85	−71.4		10	88	−62.8		7	86	−67.0	
18,000					10	72	−71.4		6	74	−62.9					
19,000					6	60	−72.2									

Altitude (meters) m. s. l.	Omaha, Nebr. (300 m.)				Sault Ste. Marie, Mich. (221 m.)				Washington, D. C.[1] (13 m.)			
	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.
Surface	31	979	−1.9	78	31	986	−10.5	89	29	1,017	0.5	81
500	31	955	−0.5	73	31	952	−10.1	90	29	958	0.8	66
1,000	31	897	0.2	67	31	892	−10.3	89	29	901	−0.5	63
1,500	31	843	−0.9	61	31	835	−11.1	85	29	846	−1.8	63
2,000	31	791	−3.4	58	31	783	−12.8	81	29	795	−2.6	63
2,500	31	742	−6.3	56	31	733	−14.6	78	29	746	−5.1	62
3,000	31	696	−9.1	55	31	686	−16.2	75	29	699	−7.2	60
4,000	31	611	−14.9	55	31	600	−21.1	73	29	614	−12.0	54
5,000	31	534	−21.6	55	30	523	−27.3	71	29	538	−18.1	51
6,000	31	466	−28.4	53	30	454	−33.8	69	29	470	−24.5	51
7,000	31	404	−35.9	52	30	393	−40.2	68	27	409	−31.1	50
8,000	30	349	−43.0		29	339	−46.1		26	355	−38.1	
9,000	30	300	−48.8		29	291	−50.0		24	306	−44.0	
10,000	30	258	−52.7		28	250	−51.3		22	263	−48.9	
11,000	29	221	−55.6		25	214	−51.0		18	226	−52.8	
12,000	27	188	−57.3		23	183	−52.2		15	194	−54.9	
13,000	26	160	−58.4		20	157	−53.1		14	166	−55.5	
14,000	23	137	−59.5		16	134	−53.6		10	142	−57.4	
15,000	21	117	−61.2		10	115	−55.5		9	121	−59.6	
16,000	19	99	−64.0		9	97	−57.4		8	104	−61.8	
17,000	17	84	−65.2						6	89	−63.2	
18,000	9	72	−66.0									
19,000	6	61	−68.0									

Observations taken about 4 a. m., 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

[1] Navy.

NOTE.—None of the means included in this table are based on less than 15 surface or 5 standard-level observations.

Number of observations refers to pressure only as temperature and humidity data are missing for some observations at certain levels also the humidity data is not used in daily observations when the temperature is below −40° C.

TABLE 2.—*Free-air resultant winds based on pilot-balloon observations made near 5 p. m. (E. S. T.) during January 1939*

[Directions given in degrees from North (N=360°, E=90°, S=180°, W=270°)—Velocities in meters per second (Superior Figures Indicate Number of Observations]

Altitude (meters) m. s. l.	Abilene, Tex. (537 m.)		Albuquerque, N. Mex. (1,554 m.)		Atlanta, Ga. (302 m.)		Billings, Mont. (1,095 m.)		Boise, Idaho (850 m.)		Brooklyn, N. Y. (15 m.)		Brownsville, Tex. (7 m.)		Buffalo, N. Y. (220 m.)		Burlington, Vt. (132 m.)		Charleston, S. C. (18 m.)		Cheyenne, Wyo. (1,873 m.)		Chicago, Ill. (192 m.)		Cincinnati, Ohio (157 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	239	3.4^{30}	311	1.7^{31}	270	3.0^{27}	282	4.7^{31}	319	0.4^{27}	288	3.7^{28}	130	3.0^{29}	254	3.2^{26}	216	1.8^{27}	232	1.6^{20}	274	5.2^{29}	252	2.0^{31}	233	2.5^{29}
500	----	----	----	----	277	4.2^{27}	----	----	----	----	285	6.3^{27}	145	4.5^{29}	247	5.8^{26}	234	4.0^{27}	237	4.9^{30}	----	----	255	4.7^{23}	230	5.7^{19}
1,000	230	4.8^{30}	----	----	263	5.5^{27}	----	----	319	0.5^{27}	287	10.7^{21}	306	0.4^{21}	245	10.5^{16}	267	6.9^{25}	257	7.2^{26}	----	----	252	8.7^{19}	237	9.9^{28}
1,500	252	6.1^{30}	----	----	266	7.5^{24}	271	8.5^{30}	286	0.7^{27}	288	14.0^{21}	266	3.9^{19}	256	11.9^{13}	288	9.5^{20}	265	10.9^{25}	----	----	270	12.7^{13}	245	13.3^{19}
2,000	256	9.6^{29}	288	2.8^{30}	274	10.2^{22}	280	8.8^{30}	281	3.4^{26}	289	16.1^{19}	241	8.7^{17}	----	----	298	12.4^{12}	272	11.5^{23}	281	6.6^{29}	273	15.8^{10}	266	15.5^{16}
2,500	258	11.2^{28}	283	6.6^{29}	274	12.8^{21}	289	9.7^{30}	288	7.0^{24}	295	18.2^{16}	254	8.5^{13}	----	----	295	13.4^{11}	270	13.6^{23}	287	9.4^{29}	----	----	274	15.5^{14}
3,000	254	13.0^{25}	298	8.7^{25}	275	13.2^{18}	289	10.5^{27}	202	8.3^{21}	291	20.6^{15}	264	10.1^{11}	----	----	----	----	275	15.5^{20}	291	10.9^{29}	----	----	----	----
4,000	254	15.6^{20}	296	12.9^{23}	273	16.0^{13}	298	16.4^{19}	304	10.2^{14}	----	----	----	----	----	----	----	----	271	16.5^{15}	294	12.5^{27}	----	----	----	----
5,000	265	19.2^{18}	302	15.9^{20}	----	----	298	21.6^{14}	----	----	----	----	----	----	----	----	----	----	----	----	295	14.0^{16}	----	----	----	----
6,000	256	19.7^{12}	314	20.1^{16}	----	----	299	21.3^{13}	----	----	----	----	----	----	----	----	----	----	----	----	302	18.3^{13}	----	----	----	----
8,000	----	----	317	20.4^{13}	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
10,000	----	----	309	21.3^{12}	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Altitude (meters) m. s. l.	El Paso, Tex. (1,196 m.)		Fargo, N. Dak. (283 m.)		Greensboro, N. C. (271 m.)		Havre, Mont. (766 m.)		Houston, Tex. (21 m.)		Huron, S. Dak. (393 m.)		Las Vegas, Nev. (570 m.)		Little Rock, Ark. (m.)		Medford, Oreg. (410 m.)		Miami, Fla. (10 m.)		Minneapolis, Minn. (261 m.)		Nashville, Tenn. (194 m.)		New Orleans, La. (19 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	259	2.7^{31}	314	1.5^{31}	265	2.1^{25}	259	3.8^{24}	156	0.9^{28}	314	1.5^{30}	34	0.6^{30}	----	----	210	0.5^{21}	104	2.6^{31}	257	0.5^{28}	230	2.5^{27}	200	0.6^{31}
500	----	----	224	1.4^{23}	256	4.2^{28}	----	----	196	1.9^{25}	304	2.2^{30}	----	----	----	----	215	0.6^{17}	131	2.9^{31}	264	1.4^{25}	223	4.3^{27}	205	2.2^{31}
1,000	----	----	263	3.3^{21}	256	6.9^{28}	267	8.1^{29}	244	2.4^{25}	295	5.8^{26}	45	0.8^{30}	----	----	221	2.4^{17}	172	1.5^{30}	266	3.8^{22}	236	6.3^{26}	234	3.7^{26}
1,500	262	3.7^{31}	288	6.0^{19}	266	9.4^{28}	282	11.8^{29}	263	6.1^{21}	298	9.1^{24}	340	1.2^{30}	----	----	213	4.3^{17}	245	2.7^{27}	278	7.0^{20}	254	9.4^{24}	259	5.2^{23}
2,000	266	5.6^{31}	301	8.2^{16}	275	12.0^{27}	288	12.3^{28}	268	10.6^{19}	296	9.8^{22}	306	2.1^{30}	----	----	243	5.6^{17}	255	3.8^{28}	279	8.9^{17}	260	12.3^{22}	266	7.3^{19}
2,500	282	7.8^{30}	293	9.8^{14}	277	14.4^{26}	292	13.5^{25}	275	12.8^{16}	291	11.0^{21}	330	3.9^{29}	----	----	259	6.2^{12}	264	5.1^{31}	285	11.0^{14}	264	14.7^{21}	275	6.9^{17}
3,000	286	9.5^{30}	290	11.5^{13}	273	18.2^{26}	292	13.1^{21}	277	11.8^{12}	289	13.1^{21}	324	5.2^{25}	----	----	280	8.6^{11}	274	6.7^{16}	282	11.4^{12}	272	15.7^{15}	273	9.0^{16}
4,000	275	11.5^{25}	292	15.2^{13}	278	22.9^{23}	299	16.5^{12}	270	12.9^{10}	291	14.8^{19}	314	7.2^{25}	----	----	----	----	265	8.9^{15}	----	----	268	16.4^{10}	265	14.6^{14}
5,000	278	16.0^{22}	----	----	279	24.1^{14}	----	----	----	----	289	17.7^{16}	314	10.4^{22}	----	----	----	----	262	9.9^{12}	----	----	----	----	257	15.8^{16}
6,000	275	17.9^{15}	----	----	275	27.3^{10}	----	----	----	----	295	20.8^{17}	312	12.3^{22}	----	----	----	----	----	----	----	----	----	----	----	----
8,000	----	----	----	----	----	----	----	----	----	----	294	23.1^{13}	341	14.9^{16}	----	----	----	----	----	----	----	----	----	----	----	----
10,000	----	----	----	----	----	----	----	----	----	----	279	24.1^{11}	335	22.0^{15}	----	----	----	----	----	----	----	----	----	----	----	----
12,000	----	----	----	----	----	----	----	----	----	----	----	----	313	16.2^{12}	----	----	----	----	----	----	----	----	----	----	----	----
14,000	----	----	----	----	----	----	----	----	----	----	----	----	293	15.4^{10}	----	----	----	----	----	----	----	----	----	----	----	----

Altitude (meters) m. s. l.	Oakland, Calif. (8 m.)		Oklahoma City, Okla. (402 m.)		Omaha, Nebr. (306 m.)		Reno, Nev. (1,346 m.)		St. Louis, Mo. (170 m.)		Salt Lake City, Utah (1,294 m.)		San Diego, Calif. (15 m.)		San Juan, P. R. (16 m.)		Sault Ste. Marie, Mich. (198 m.)		Seattle, Wash. (14 m.)		Spokane, Wash., (603 m.)		Washington D. C. (10 m.)		Winslow, Ariz. (1,488 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	279	1.3^{27}	235	2.3^{31}	302	1.7^{29}	241	1.7^{31}	235	1.9^{26}	236	1.2^{30}	268	2.4^{25}	80	6.6^{31}	257	0.8^{21}	205	3.4^{27}	210	1.8^{25}	291	2.1^{26}	282	2.9^{31}
500	350	2.0^{27}	227	3.3^{29}	283	2.1^{29}	----	----	236	5.6^{26}	----	----	300	1.4^{28}	90	8.4^{31}	279	2.0^{21}	201	6.4^{27}	----	----	265	5.3^{26}	----	----
1,000	359	4.2^{26}	241	5.1^{26}	276	4.1^{27}	----	----	256	8.6^{25}	----	----	45	1.1^{26}	95	7.8^{31}	279	3.8^{20}	209	8.6^{19}	212	3.8^{25}	263	8.7^{26}	----	----
1,500	343	5.1^{24}	256	7.6^{29}	282	6.8^{26}	235	1.7^{31}	276	12.3^{23}	204	1.8^{30}	16	2.4^{21}	96	6.6^{31}	315	5.1^{16}	225	7.4^{16}	218	6.7^{16}	284	12.6^{25}	----	----
2,000	341	6.5^{22}	257	8.9^{27}	285	9.3^{21}	249	2.3^{31}	284	14.3^{21}	213	1.7^{29}	4	4.4^{22}	100	5.9^{26}	307	5.0^{14}	232	9.2^{10}	233	7.7^{14}	289	17.8^{23}	274	3.0^{30}
2,500	322	7.0^{20}	256	11.3^{26}	288	11.5^{19}	266	3.5^{30}	286	14.8^{20}	271	2.8^{29}	355	4.2^{19}	87	6.1^{15}	305	6.6^{13}	----	----	239	8.0^{12}	285	19.8^{21}	284	4.7^{30}
3,000	326	10.1^{19}	261	13.2^{26}	286	13.7^{16}	283	5.6^{27}	283	14.5^{16}	285	5.5^{25}	336	5.4^{17}	83	4.7^{19}	309	9.0^{12}	----	----	253	10.4^{11}	282	19.4^{19}	280	5.3^{29}
4,000	334	10.7^{15}	265	17.6^{24}	285	19.4^{15}	305	9.7^{23}	----	----	286	7.9^{16}	323	6.6^{14}	89	3.5^{12}	----	----	----	----	----	----	271	22.1^{12}	297	7.8^{25}
5,000	343	13.8^{11}	274	19.7^{19}	285	21.7^{15}	321	13.8^{19}	----	----	287	10.3^{13}	311	9.2^{10}	----	----	----	----	----	----	----	----	----	----	306	11.2^{23}
6,000	----	----	275	23.9^{13}	289	22.4^{14}	322	15.4^{17}	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	311	14.7^{22}
8,000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	315	17.5^{19}
10,000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	311	17.3^{13}
12,000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	302	17.7^{10}
14,000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	284	18.6^{10}

TABLE 3.—*Maximum free-air wind velocities (M. P. S.), for different sections of the United States based on pilot balloon observations during January 1939*

Section	Surface to 2,500 meters (m. s. l.)					Between 2,500 and 5,000 meters (m. s. l.)					Above 5,000 meters (m. s. l.)				
	Maximum velocity	Direction	Altitude (m.) M. S. L.	Date	Station	Maximum velocity	Direction	Altitude (m.) M. S. L.	Date	Station	Maximum velocity	Direction	Altitude (m.) M. S. L.	Date	Station
Northeast [1]	47.8	WNW	900	25	Albany, N. Y.	51.2	NW	3,720	25	Pittsburgh, Pa.	53.5	WNW	5,580	12	Albany, N. Y.
East-Central [2]	43.4	NW	1,180	31	Washington, D. C.	63.4	W	4,320	26	Greensboro, N. C.	64.0	W	11,800	8	Nashville, Tenn.
Southeast [3]	42.0	SW	2,440	30	Jacksonville, Fla.	47.6	WSW	3,520	18	Jacksonville, Fla.	41.0	WNW	11,450	8	Charleston, S. C.
North-Central [4]	39.0	WNW	2,400	1	Bismark, N. Dak.	49.6	NNW	4,990	27	Fargo, N. Dak.	72.5	NW	10,920	26	Huron, S. Dak.
Central [5]	50.2	SW	2,320	9	Wichita, Kans.	50.0	NW	4,960	26	Omaha, Nebr.	58.0	WNW	9,560	19	Wichita, Kans.
South-Central [6]	37.7	SW	1,530	31	Amarillo, Tex.	45.7	W	5,000	17	Abilene, Tex.	55.2	WNW	9,040	30	Del Rio, Tex.
Northwest [7]	40.2	W	1,940	2	Havre, Mont.	53.5	SW	4,500	1	Medford, Oreg.	72.0	NNW	6,580	14	Billings, Mont.
West-Central [8]	29.4	W	2,290	19	Cheyenne, Wyo.	54.0	WNW	3,480	25	Rock Springs, Wyo.	77.5	WSW	9,350	3	Redding, Calif.
Southwest [9]	43.0	W	2,370	28	El Paso, Tex.	56.0	NNW	5,000	18	Albuquerque, N. Mex.	95.5	NNW	8,440	14	Albuquerque, N. Mex.

[1] Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and northern Ohio.
[2] Delaware, Maryland, Virginia, West Virginia, southern Ohio, Kentucky, eastern Tennessee, and North Carolina.
[3] South Carolina, Georgia, Florida, and Alabama.
[4] Michigan, Wisconsin, Minnesota, North Dakota, and South Dakota.
[5] Indiana, Illinois, Iowa, Nebraska, Kansas, and Missouri.
[6] Mississippi, Arkansas, Louisiana, Oklahoma, Texas (except El Paso), and western Tennessee.
[7] Montana, Idaho, Washington, and Oregon.
[8] Wyoming, Colorado, Utah, northern Nevada, and northern California.
[9] Southern California, southern Nevada, Arizona, New Mexico, and extreme west Texas.

TABLE 4.—*Mean altitudes and temperatures of significant points identifiable as tropopauses during January 1939, classified according to the potential temperatures (10-degree intervals between 290 and 399° A.) with which they are identified. (Based on radiosonde observations.) All actual temperatures are in degrees centigrade below zero*

Potential temperatures °A.	Fargo, N. Dak.			Nashville, Tenn.			Oakland, Calif.			Oklahoma City, Okla.			Omaha, Nebr.			Sault Ste. Marie, Mich.			Washington, D. C.		
	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature
290–299	1	6.5	50.0				1	6.6	41.0				4	7.3	48.2	12	7.0	47.3			
300–309	17	8.4	53.2	2	7.3	39.5	2	7.0	36.5				10	7.9	48.6	19	7.9	48.9	5	7.4	42.6
310–319	14	9.5	57.2	4	7.8	38.2	4	8.8	47.0	10	8.8	47.4	19	9.4	54.8	17	9.1	54.6	7	8.8	46.8
320–329	9	9.9	54.4	15	9.5	47.2	16	10.7	56.4	16	10.3	53.8	16	10.4	55.9	10	9.9	53.7	10	10.0	53.5
330–339	3	10.3	53.3	18	11.7	61.3	12	11.3	57.1	13	11.4	58.3	8	11.4	60.3	4	11.4	60.5	6	11.2	57.5
340–349				10	11.8	57.9	9	12.3	60.1	6	12.5	62.1	4	12.2	58.0	4	11.0	54.7	3	12.2	60.3
350–359	2	12.0	58.0	4	13.7	67.0	4	12.3	55.0	3	11.1	51.3	2	12.2	53.0	3	12.0	56.7			
360–369	2	12.2	55.0	7	14.2	67.0	1	15.1	73.0				3	13.0	55.7	4	12.4	53.5			
370–379				3	15.0	67.7	7	14.0	59.0	4	15.0	71.2	6	14.2	61.3	5	12.7	52.2			
380–389				3	15.9	73.3	2	14.4	59.0				2	14.9	65.5	1	13.1	51.0			
390–399				2	16.8	75.0	2	15.9	63.3	1	14.5	57.0	4	14.8	57.0	1	13.5	50.0	2	15.6	64.0
All (weighted mean)		9.4	54.8		11.7	57.8		11.6	56.5		11.0	55.9		10.6	55.7		9.4	52.1		10.1	52.4
Weighted mean potential temperature, °A	317.4			341.7			339.1			334.1			331.3			322.5			327.2		